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PHYTOTOXICOLOGY INVESTIGATION REPORT: OZONE INJURY TO SENSITIVE CROPS IN GREY AND BRUCE COUNTIES RELATIVE TO OTHER LOCATIONS IN SOUTHERN ONTARIO (1995)

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IN SOUTHERN ONTARIO (1995)

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Executive Summary

The crop inspections in July (1995) revealed trace to very light ozone injury overall on the injured tomato and potato plants in Grey (Owen Sound) and Bruce (Tiverton) counties. This was similar to the range in injury on tomato and potato plants that were affected elsewhere across southern Ontario in 1995 and previous years. The injury scores for both crops for Tiverton were slightly higher than for Owen Sound, but were comparable to the highest scores for more southern locations of the province. The injury scores for Owen Sound were comparable to the lowest scores.

Ozone injury in the trace to moderate range was observed in August on the commercial white bean plantings that were injured in Grey and Bruce Counties, with the foliar injury in the Meaford (Grey) area being slightly more severe than in the Chesley and Bervie areas (Bruce), which were closer to Tiverton. However, the ozone injury on white bean crops in Grey and Bruce Counties did not approach the severe category as it did in more southern areas of the province in 1995 and other years. White bean plants at Harrow (Essex) and Huron Park (Huron) had the most severe ozone injury and the highest injury scores overall, which fell in the severe category in 1995.

The presence of ozone injury at most locations, combined with the ambient ozone data, confirms that the ozone concentrations encountered during the 1995 growing season were injurious to sensitive crops in southern Ontario.

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Phytotoxicology Investigation Report: Ozone Injury to Sensitive Crops in Grey and Bruce Counties Relative to Other Locations in Southern Ontario (1995)

INTRODUCTION

In January 1995, the chair of the Environmental Waste Management Advisory Committee (EWMAC) of the City of Owen Sound forwarded a letter to Mr. G. Grosse, of the Ministry of Environment and Energy (MOEE) Southwest Region London office, expressing concern about ground-level concentrations of ozone in Owen Sound over the summer. The City is concerned because of the high ozone levels that have been measured upwind at Tiverton, and the increase in respiratory disease in the area. Because of these concerns, and the absence of an ozone monitor in Owen Sound, Mr. Grosse requested in January (1995) that the Phytotoxicology Section's ozone surveys planned for 1995 be extended north to include crops in Grey and Bruce Counties. In 1995, tomato, potato and whitebean plantings in Grey and Bruce counties were inspected during the regular province-wide surveys in July (tomato/potato) and August (whitebean).

Since 1971, personnel of the Phytotoxicology Section have conducted annual assessment surveys throughout the major crop production areas in southern Ontario as a means to assess and compare the annual severity of foliar ozone injury on sensitive Ontario crops (eg., tomatoes, potatoes, white beans). A few years were missed because of program constraints.

Ozone has long been recognized as the major component of the photochemical oxidant complex and as one of the most damaging of all air pollutants affecting vegetation. Ozone is commonly associated with urban atmospheres due to precursor pollutants in these areas. However, its presence extends into rural and uninhabited areas as a result of long range transport by regional air movements. In southern Ontario, high ozone levels are generally associated with regional southerly air flows which are carried across the lower Great Lakes after having passed over numerous urban and industrialized areas of the United States. Contributing to this influx pattern are the localized, domestic downwind urban effects which can add to the already high background levels.

OZONE INJURY SURVEYS

The crop surveys in 1995 were conducted to compare the severity of ozone injury to sensitive crops in Grey and Bruce Counties (particularly in Owen Sound and Tiverton) with other locations across Southern Ontario. The surveys were conducted by R. Emerson of the Phytotoxicology Section. Numerous photographs of ozone injury were taken, and specimens of injured leaves were collected and placed in a plant press for subsequent storage in the Section's herbarium.

Tomato and Potato Survey

In July 1995, foliage on tomato and/or potato plants was inspected for ozone injury in 12 home gardens in Owen Sound (July 10) and in three gardens in the Tiverton area (July 11). Owen Sound is located on Georgian Bay and five of the 12 gardens were situated in the valley which extends north and south through the central part of the city (see Figure 1). Tiverton is a small rural community neighbouring the east shore of Lake Huron (Figure 2). Prior to inspecting the sites in Owen Sound and Tiverton, permission was obtained from the property owner. The name of the tomato and/or potato varieties being grown, if known, also were obtained.

Experimental tomato and/or potato plantings, as in previous years, also were inspected at the Ontario Ministy of Agriculture, Food & Rural Affairs (OMAFRA) or Canada Department of Agriculture (CDA) experimental stations at Harrow (July 10), Ridgetown (July 12), Cambridge (July 12), Simcoe (July 13), and Kemptville (July 19) (see Figure 2).

Ozone injury on tomatoes occurs initially on the lower leaf surface as copper or grey-coloured lesions. On potato foliage, ozone injury can occur on both upper and lower surfaces. The symptoms on the upper surface appear as blackened stipples. The symptoms on the undersurface (silver-grey or bronze lesions) very closely resemble the injury documented on tomato foliage. On both crops, the undersurface lesions usually are small and circular and can coalesce and become bifacial resulting in larger irregular-shaped lesions on both surfaces. The lesions may be scattered across the lower (abaxial) leaf surface, or be confined near the tip, base, or margins of the leaf blade. Moreover, the injury is usually present on similar-aged opposite leaves, and usually is more pronounced on middle-aged and older compound leaves. The foliar symptoms usually appear sometime between mid June to mid-July when the plants have flowered and fruits or tubers are developing. Ozone also can result in glazing (glassy appearance) on the under surface of tomato and potato leaves.

Normally, at each location, foliage was inspected for ozone injury on two representative plants (main shoots) of each cultivar, and the average injury (%) to each compound leaf was determined. The average injury to each plant was calculated using the formula A/B x C, where A = the number of injured leaves; B = the total number of examined leaves, and C = the average injury to all affected leaves. For example, Site 1 in Table 1 had a beefsteak tomato plant with injury on five out of 10 examined leaves, with the average injury to the five affected compound leaves being 1% when rounded-off. Using the formula, this works out to be 5/10 x 1% = 0.05%, which falls into the trace (>0-1%) category.

In order to compare the injury severity between the locations inspected in 1995, the

injury ratings for each location were crunched down into a single numerical injury index score using a formula which takes into account the injury severity as well as the percentage of injured plants at each location. The same approach has been used in previous surveys to compare the injury severity between locations and years. For example, the injury index score for Owen Sound was derived by determining the percentage of plants in each injury category (trace, light etc.) relative to the total number of plants examined, and then multiplying the percentage (decimal) values by the following corresponding weighting factors - trace (x 5); light (x 25); moderate (x 50) and severe (x 100). In Owen Sound, 10 tomato plants (0.23 or 23%) out of the 43 examined plants had trace injury only. Using the formula and incorporating the weighting factor for trace (5), the total injury index score for Owen Sound works out to be 0.23 x 5 = 1.15. This rounds off to an even number of 1, out of a maximum 100.

White bean Survey

On August 15 1995, commercial white bean fields were inspected for ozone injury near Meaford in Grey County, and near Chesley and Bervie in Bruce County. OMAFRA was consulted for these grower contacts because of the limited and spotty white bean acreage in these counties. White bean crops are more common in southern counties. The investigator contacted each grower for permission and to obtain the name of the varieties grown.

The white bean variety plots at Brussells (August 16), Huron Park (August 16), Harrow (August 17), Shetland (August 17), Ridgetown (August 16), Elora (August 15), and Winchester (August 23) also were examined (see Figure 2). With the exception of Ridgetown, all of these locations had a Provincial white bean variety registration plot. The white bean plots at Huron Park (OMAFRA), Harrow (CDA), Ridgetown (OMAFRA), and Elora (University of Guelph) have been inspected annually for several years.

Ozone injury to white bean foliage develops in the period between flowering and normal senescence and results in tiny blackish or reddish brown stipples on the upper-leaf-surface. The injured leaves appear bronzed, with older leaves becoming senescent and abscising prematurely. The severity of bronzing is largely influenced by the stage of plant development, with injury usually being more severe on older plants.

At each station (variety trial plot), foliage was inspected on numerous varieties, including recommended varieties for Ontario. The plants inspected in each variety plot were evaluated for foliar ozone damage and a numerical injury rating (from 0 to 6) was assigned that represented the average severity of injury to the plot. The seven injury rating levels fall into five injury severity categories: no injury (0), trace (rating 1), light (ratings 2-3), moderate (rating 4) and severe (ratings 5-6). The injury rating categories are described below. The same method was used in rating the commercial white bean plantings near Meaford, Chesley and Bervie.

Injury Rating	*Criteria*
0	*No oxidant symptoms observed*
1	*Scattered stippling on a few of the oldest leaves*

2 *Scattered stippling over most of the leaves*

3 *Moderate stippling or bronzing over a few of the leaves*

4 *Moderate stippling or bronzing over most of the leaves with some coalescence into flecks*

5 *Severe stippling or bronzing coalescing into necrotic flecks on many of the leaves; some premature leaf senescence and initial defoliation*

6 *Severe stippling or bronzing and coalescence on almost all leaves; plants prematurely senescent and defoliation occurring*

In order to compare the overall severity of ozone injury on white beans between locations where numerous varieties were inspected (e.g. registration plots), the same injury scoring method that was applied to the tomato and potato data was used so that the white bean injury ratings could be crunched down into a single numerical score for each location. In calculating the injury index score for each location, the total number of injury ratings (observations) was tallied and the percentage of ratings in each injury category (trace, light etc.) was calculated. The percentage values (decimal) were then multiplied by a corresponding weighting factor - trace: 5; light: 10; moderate: 50; and severe: 100. Then, the separate indices were added to generate a total injury severity index score (see example at bottom of Table 4). The higher the injury index score, the higher the number of ratings in the more severe injury categories. For purposes of interpretation, a score between 1 and < 20 is classed as trace; between 20 and 35 light; and between 36 and 50 moderate. A score of greater than 50 is classed as severe. An injury index score was also caluclated for the commercial white bean locations that were inspected in Grey and Bruce Counties.

RESULTS OF OZONE INJURY SURVEYS

Tomato and Potato

In Owen Sound (see Table 1), ozone injury was observed on the foliage of 17 (out of 67) tomato and potato plants in seven of the 12 examined gardens (1, 6, 7, 8, 10, 11, 12). The injured tomato plants in gardens 1, 6, 8, 11 and 12 had trace injury (>0-1%) overall, while the injured potato plants in gardens 6, 7, 10 and 11 had trace or very light (< 3%) injury overall. The slightly more severe injury on potato foliage at Site 10 (varieties unknown) and Site 11 (Yukon Gold) in the valley could be due to these varieties being more sensitive to ozone than other varieties. Yukon Gold is known to be sensitive to ozone. Several other factors also can influence plant response to ozone (climatic factors, soil type, soil fertility, soil moisture, disease and insect pressure, cultural practices), resulting in variability in injury between plants and locations. Most of the inspected tomato and potato plants (11 out of 15) in Tiverton also had trace or light injury overall. The tomato and potato plants with light injury in garden 3 had very light injury (<3%) overall (see Table 2).

Table 3 shows that the tomato plants that were injured at Owen Sound and Tiverton had a similar severity of ozone injury as the injured tomato plants at Harrow, Ridgetown, and Simcoe (trace or light). The injury index score for each location also is shown. The higher the

injury score, the greater the injury severity and/or the percentage of injured plants. Tiverton (5) and Harrow (5) had slightly higher injury scores than the other locations, but even these scores reflect very light injury. Owen Sound (1) had the lowest score.

Ozone injury also was observed on potato plants in all areas, including Owen Sound and Tiverton (Table 3). All injured potato plants had trace or light ozone injury, with the exception of the Norland potato variety at Ridgetown, which had more severe injury in the moderate (>10-35%) category. Because the Norland variety is extremely ozone sensitive and was not present at other locations, it was excluded from the calculation of the injury index score for Ridgetown. Table 3 shows that Tiverton (8) and Simcoe (5) had the highest injury scores, while Owen Sound, Ridgetown, Cambridge, and Kemptville had lower but similar scores (2-3). The scores for all locations are low and reflect very light injury overall. Tiverton had the highest score because of a larger percentage of injured potato plants (100%) relative to the other locations.

In most previous years, the injury to tomato and potato crops across southern Ontario also was trace to very light overall.

Whitebean

The inspections of the commercial white bean fields in Grey and Bruce Counties in August (1995) revealed trace or light ozone injury near Chesley (Bruce), and trace or moderate injury near Meaford (Grey). No ozone injury was observed at Bervie (Bruce) (see Table 4). The injury to white bean foliage at the experimental sites visited across the province was generally more severe, ranging from trace or light through to moderate or severe. The corresponding injury index scores also revealed that the white bean crops were less injured in Grey and Bruce counties relative to the other locations. The white bean plots at Huron Park (Huron) and Harrow (Essex) had the most severe ozone injury in 1995.

Ozone injury ranging from trace to severe has been observed on the foliage of whitebean crops in the major production areas in most years since 1971.

AMBIENT OZONE CONCENTRATIONS

Table 5 summarizes the ambient ozone levels that were encountered across southern Ontario prior to the tomato/potato survey in July. Ambient ozone levels were, at times, at or above the MOEE's 80 ppb hourly criterion in June and/or July, particulary at Kitchener, Tiverton, Merlin and Simcoe. This criterion was established to protect sensitive vegetation, and ambient ozone levels greater than 80 ppb are potentially injurious to sensitive crops. Table 6 shows that ambient ozone levels in the white bean production areas, at times, also were at or above 80 ppb in July and August, particularly at Merlin, Tiverton and Windsor. The ozone data in Tables 5 and 6 are provisional upon QA/QC validation, which was incomplete at the time this report was written.

CONCLUSION

The crop inspections in July (1995) revealed trace to very light ozone injury overall on the injured tomato and potato plants in Grey (Owen Sound) and Bruce (Tiverton) counties. This was

similar to the range in injury on tomato and potato plants that were affected elsewhere across southern Ontario in 1995 and previous years. The injury scores for both crops for Tiverton were slightly higher than for Owen Sound, but were comparable to the highest scores for more southern locations of the province. The injury scores for Owen Sound were comparable to the lowest scores.

Ozone injury in the trace to moderate range was observed in August on the commercial white bean plantings that were injured in Grey and Bruce Counties, with the foliar injury in the Meaford (Grey) area being slightly more severe than in the Chesley and Bervie areas (Bruce), which were closer to Tiverton. However, the ozone injury on white bean crops in Grey and Bruce Counties did not approach the severe category as it did in more southern areas of the province in 1995 and other years. White bean plants at Harrow (Essex) and Huron Park (Huron) had the most severe ozone injury and the highest injury scores overall, which fell in the severe category in 1995.

The presence of ozone injury at most locations, combined with the ambient ozone data, confirms that the ozone concentrations encountered during the 1995 growing season were injurious to sensitive crops in southern Ontario.

Figure 1: Approximate Location of Tomato and Potato Gardens Inspected in Owen Sound.

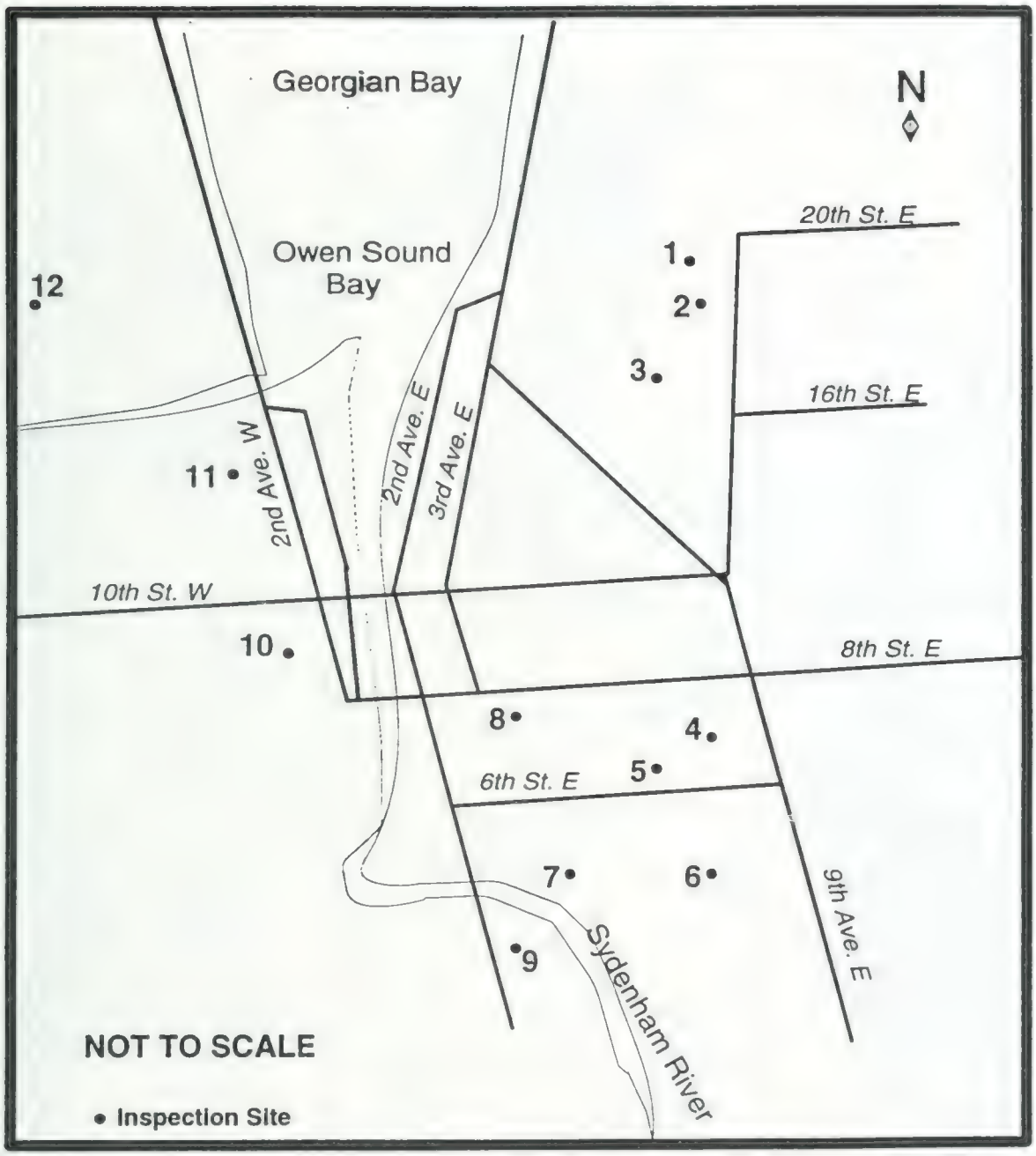
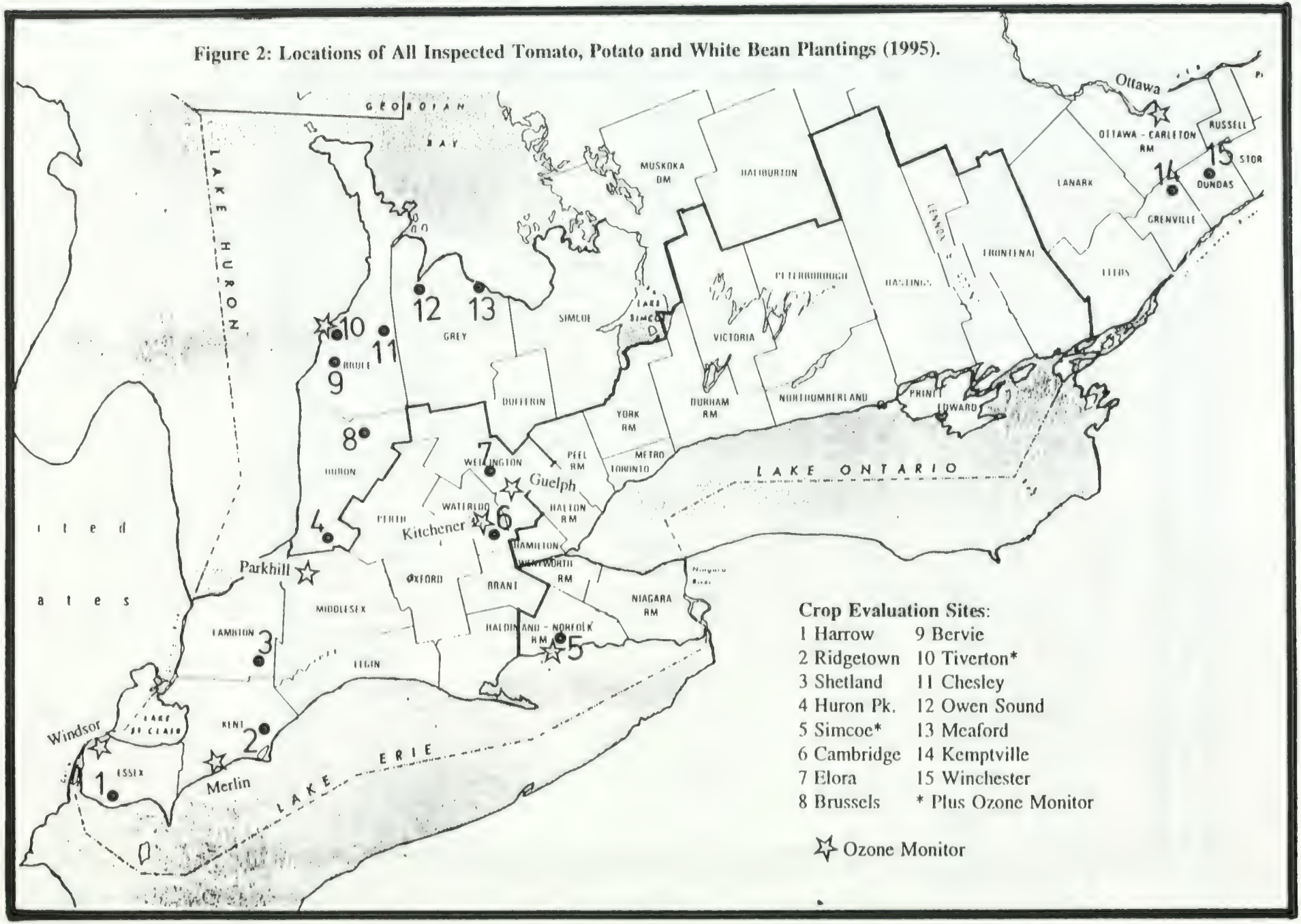


Figure 2: Locations of All Inspected Tomato, Potato and White Bean Plantings (1995).



Crop Evaluation Sites:

1 Harrow	9 Bervie
2 Ridgetown	10 Tiverton*
3 Shetland	11 Chesley
4 Huron Pk.	12 Owen Sound
5 Simcoe*	13 Meaford
6 Cambridge	14 Kemptville
7 Elora	15 Winchester
8 Brussels	* Plus Ozone Monitor

☆ Ozone Monitor

Table 1: Ozone Injury to Tomato and Potato Plants: Owen Sound - July 10, 1995.

Site No.	Crop	Varieties	Plants Examined	Plants Injured	Overall Foliar Injury
1	Tomato	Beefsteak	2	2	*Trace*
2	Tomato	Early Girl	2	0	None
	Potato	Kennebec	2	0	None
3	Tomato	Unknown	2	0	None
	Potato	Unknown	2	0	None
4	Tomato	Fantastic Glamour	2 2	0 0	None None
5	Tomato	Beefsteak	2	0	None
	Potato	Cheiftain Kennebec	2 2	0 0	None None
6	Tomato	Bonny Best Cherry Type	2 2	0 0	None None
	Potato	Sebago	3	1	*Trace*
7*	Tomato	Ultra Girl	2	0	None
	Potato	Cheiftain	3	1	*Trace*
8*	Tomato	Beefsteak Big Boy Bonny Best	2 2 2	0 2 1	None *Trace* *Trace*
	Potato	Unknown	2	0	None
9*	Tomato	Beefcake Beefsteak Ultra Girl	1 1 1	0 0 0	None None None
	Potato	Cheiftain	2	0	None
10*	Tomato	Beefsteak Bonny Best Cherry Type	2 2 2	0 0 0	None None None
	Potato	Unknown Unknown	2 2	2 1	*Trace* *Light*
11*	Tomato	Better Boy Bonny Best Glamour	2 2 2	1 0 0	*Trace* None None
	Potato	Yukon Gold	2	2	*Trace - Light*
12	Tomato	Beefsteak H-1350	2 2	2 2	*Trace* *Trace*
Summary (All Sites)	Tomato	11 Var. Minimum	43	10	*Trace*
	Potato	4 Var. Minimum	24	7	*Trace - Light*

* Garden in valley. Ozone injury categories: None = No injury, Trace = >0 to 1%, Light = >1 to 10%

Table 2: Ozone Injury to Tomato and Potato Plants: Tiverton - July 11, 1995.					
Site No.	**Crop**	**Varieties**	**Plants Examined**	**Plants Injured**	**Overall Foliar Injury**
1	Tomato	Ultra Girl	2	0	None
		Unknown	2	0	None
	Potato	Sebago/Kennebec	3	3	***Trace***
2	Tomato	Beefsteak	2	2	***Trace***
	Potato	Cheiftain	2	2	***Trace***
3	Tomato	Unknown	2	2	***Trace - Light***
	Potato	Unknown	2	2	***Trace - Light***
Summary (All Sites)	Tomato	2 Var. Minimum	8	4	***Trace - Light***
	Potato	2-3 Var. Minimum	7	7	***Trace - Light***

*Ozone injury categories: None = No injury; Trace = >0 to 1%; Light = >1 to 10%.

Table 3: Ozone Injury to Tomato and Potato Plants in Owen Sound and Tiverton Relative to Other Locations in Southern Ontario (1995).

County	Location	Number (No.) of Varieties and Plants Examined		No. of Plants with Ozone Injury	Overall Foliar Injury on Affected Plants	Injury Index Score **
		Varieties	Plants			
Tomato Plantings						
Grey	Owen Sound	*10-11*	*43*	*10*	*Trace*	*1*
Bruce	Tiverton	*2-4*	*8*	*4*	*Trace to Light*	*5*
Essex	Harrow*	*14*	*28*	*15*	*Trace to Light*	*5*
Kent	Ridgetown*	*10*	*19*	*13*	*Trace*	*3*
Haldimand -Norfolk	Simcoe*	*9*	*19*	*10*	*Trace to Light*	*4*
Potato Plantings						
Grey	Owen Sound	*4-8*	*24*	*7*	*Trace to Light*	*3*
Bruce	Tiverton	*2-3*	*7*	*7*	*Trace to Light*	*8*
Kent	Ridgetown*	*9*	*19*	*7*	*Trace to Moderate*	*2****
Waterloo	Cambridge*	*5*	*15*	*6*	*Trace*	*2*
Haldimand -Norfolk	Simcoe*	*7*	*21*	*15*	*Trace to Light*	*5*
Leeds-Grenville	Kemptville*	*4*	*9*	*5*	*Trace*	*3*

* OMAFRA or CDA experimental station. Home gardens were inpected in Owen Sound and Tiverton

** Injury index score was derived by determining the percentage of plants in each injury category (trace, light etc.) relative to the total number of plants examined, and then multiplying the percentage (decimal) values by the following corresponding weighting factors - trace (x 5); light (x 25); moderate (x 50) and severe (x 100). The total injury index score for each location was the sum of all injury indices. For example, if 20% of plants fell in trace (0.2 x 5 = 1), and 20% in light (0.2 x 25 = 5), the total score would be 1 + 5 = 6, out of a maximum 100

*** Injury score did not include Norland injury (moderate), as this variety is extremely sensitive to ozone and was not grown elsewhere

Note: Trace - > 0 to 1%; Light - > 1 to < 3%; Moderate - >10 to 35%. < - Less than. > Greater than

Table 4: Ozone Injury to White Bean Plantings in Grey and Bruce Counties Relative to Other Areas in Southern Ontario - August 1995

County	Location	Summary of Foliar Ozone Injury Ratings							Corresponding Injury Index Score**
		No. of Varieties	Total No. of Obs.	Number (No.) of Observations (Obs.) in Each Category					
				None (0)	Trace (1)	Light (2-3)	Moderate (4)	Severe (5, 6)	
Experimental Plots*									
Wellington	Elora	16	16	0	6	2	3	5	46
Essex	Harrow	10	12	0	0	3	4	5	65
Kent	Ridgetown	5	5	0	0	3	2	0	35
Huron	Huron Park	16	16	0	0	3	7	6	65
	Brussels	16	16	0	1	5	8	2	46
Lambton	Shetland	16	16	0	4	7	3	2	35
Stormont-Glengarry-Dundas	Winchester	16	16	0	2	4	6	4	51
Commercial Fields									
Grey	Meaford	2	2	0	1	0	1	0	28
Bruce	Chesley	1	3	1	1	1	0	0	10
	Bervie	2	4	4	0	0	0	0	0

* Plot maintained by OMAFRA or CDA, with the exception of Elora (University of Guelph).

** Injury index score was derived by determining the percentage of plants in each category (trace, light, moderate, severe) and multiplying the percentage (decimal) values by the following corresponding weighting factors - trace (x 5); light (x 25); moderate (x 50) and severe (x 100). The total injury index score for each location was the sum of all injury indices For example, if 30% of plots fell in trace (0.3 x 5 = 1.5), and 30% in light (0.3 x 25 = 7.5), the total injury index score would be 1.5 + 7.5 = 9, out of a maximum 100.

Table 5: Ambient Ozone Concentrations Recorded Prior to Tomato/Potato Survey (1995). This is Provisional Data Pending QA/QC Validation.

Air Monitor (& Closest Inspection Site(s)	Ambient Ozone Concentration (ppb) (10am-4pm 7 hr. day)						
	Month of JUNE			Month of JULY*			Total hrs. 80 ppb or more or
	No. hrs. 80 ppb or more	Max. conc.	Mean	No.hrs 80 ppb or more	Max. conc.	Mean	
Tiverton (Tiverton & Owen Sound)	15	104	51	7	88	42	22
Windsor (Harrow)	10	99	45	0	73	42	10
Merlin (Ridgetown)	19	112	53	3	88	51	22
Simcoe (Simcoe)	18	101	54	2	86	48	20
Kitchener (Cambridge)	26	98	53	3	82	42	29
Ottawa (Kemptville)	8	141	45	7	161	40	15

*For period ending on day preceding the survey date - Tiverton (Jul. 10); Harrow (Jul. 12); Ridgetown (Jul. 11); Simcoe (Jul. 13); Cambridge (Jul. 12); Kemptville (Jul. 19).

Table 6: Ambient Ozone Concentrations Recorded Prior to White Bean Survey (1995). This is Provisional Data Pending QA/QC Validation.

Air Monitor (& Closest Ispection Site(s)	Ambient Ozone Concentration (ppb) (10am-4pm 7 hr. day)						
	Month of JULY			Month of AUGUST*			Total hrs. 80 ppb or more
	No. hrs. 80 ppb or more	Max. conc.	Mean	No. hrs. 80 ppb or more	Max. conc.	Mean	
Tiverton (Bervie, Chesley, Meaford)	23	142	47	2	97	40	25
Parkhill (Huron Pk., Brussels)	10	119	47	2	93	43	12
Windsor (Harrow)	17	100	48	6	87	42	23
Merlin (Ridgetown, Shetland)	26	125	59	13	121	54	39
Guelph (Elora)	8	93	47	5	108	44	13
Ottawa (Winchester)	8	161	39	4	135	35	12

* For period ending on day preceding survey date - Bervie, Chesley and Meaford (Aug. 15); Huron Pk.and Brussels (Aug. 16); Harrow (Aug. 17); Ridgetown and Shetland (Aug. 16 & 17)); Elora (Aug. 15); Winchester (Aug. 23).